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April 18, 2019

New Jersey Department of Environmental Protection
Bureau of Case Management
Mail Code 401-05F281107
P.O. Box 420
Trenton, NJ 08625-0420

Attn: Donna Gaffigan, Case Manager

Re: *IA–12 OU-2 IRM Progress Report*
Hoffmann-La Roche Inc. Site
340 Kingsland Street, Nutley, NJ 07110
NJDEP SRP P.I. No. 009949
TRC Project No. 198233

Dear Ms. Gaffigan:

On behalf of Hoffmann-La Roche Inc. (Roche), TRC Environmental Corporation (TRC) has prepared the enclosed Interim Remedial Measure (IRM) Progress Report for Operable Unit 2 (OU-2) of Investigative Area 12 (IA-12) at the former Roche Site in Nutley, New Jersey.

Two IA-12 IRMs were implemented in 2016 within IA-12 to address tetrachloroethene (PCE) and its degradation products (trichloroethene [TCE], *cis*-1,2-dichloroethene [cis-1,2-DCE], and vinyl chloride [VC], collectively referred to as PCE+) in groundwater from a breach in the Clifton-Allwood Municipal Sewer (CAMS). The Operable Unit 1 (OU-1) IRM targeted the CAMS breach and PCE+ source zone. The OU-2 IRM targeted the PCE+ plume around OU-1 and consisted of Advanced Remediation Technologies' in-well air stripping and *in situ* chemical oxidation (ART-IWAS/ISCO).

The IA-12 OU-2 IRM was implemented in 2016 in accordance with the New Jersey Pollutant Discharge Elimination System (NJPDES) - Discharge to Groundwater-Permit-By-Rule (DGW-PBR) authorization dated August 13, 2015 (later amended by DGW-PBR authorization dated October 25, 2017) and New Jersey Department of Environmental Protection (NJDEP) air permit (PCP160003) dated September 14, 2015. This Progress Report provides an overview of the IRM treatment program, including a summary of IRM operations and monitoring data.

If you have any questions or need additional information, please contact Rebecca Hollender (908-988-1710; rhollender@trcsolutions.com).

Sincerely,

TRC ENVIRONMENTAL CORPORATION

Rebecca K. Hollender, PG, LSRP
Office Practice Leader – Director of LSRP Services

cc: Ms. Dawn Pompeo, TRC Environmental Corp.
Mr. Chandra Patel, Hoffmann-La Roche Inc.

Investigative Area 12 Operable Unit-2
Interim Remedial Measure Progress Report

Hoffmann-La Roche Inc. Site
340 Kingsland Street, Nutley, New Jersey

Prepared For:

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April 18, 2019

Investigative Area–12 Operable Unit-2
Interim Remedial Measure Progress Report

Hoffmann-La Roche Inc. Site
340 Kingsland Street, Nutley, NJ

Date: 04/18/19

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

List of Figures

List of Tables

TABLE OF CONTENTS (cont'd)

List of Appendices

List of Attachments

Investigative Area 12 Operable Unit-2
Interim Remedial Measure Progress Report

Hoffmann-La Roche Site
340 Kingsland Street, Nutley, NJ

Date: 04/18/19

1.0 INTRODUCTION

On behalf of Hoffmann-La Roche Inc. (Roche), TRC Environmental Corporation (TRC) has prepared this Interim Remedial Measure (IRM) Progress Report for Operable Unit 2 (OU-2) of Investigative Area (IA)-12 at the former Roche facility (Site) located at 340 Kingsland Street, Nutley, New Jersey (Figure 1).

The Clifton-Allwood Municipal Sewer (CAMS) that traverses the Site from north to south has carried both sanitary and industrial wastewater from north of Route 3; Roche did not discharge into the CAMS. The remedial investigation (RI) for IA-12 soil areas of concern (TRC, 2013) and the Site-wide groundwater RI (TRC, 2014) identified a breach in the CAMS at IA-12 that resulted in the release of tetrachloroethene (PCE) and its degradation products (trichloroethene [TCE], *cis*-1,2-dichloroethene [cis-1,2-DCE], and vinyl chloride [VC], collectively referred to as PCE+) to groundwater, including dense non-aqueous phase liquids (DNAPL) containing PCE. To facilitate the redevelopment of the Site, an IRM was implemented to address the PCE+ impacts in the vicinity of the CAMS breach even though this release was not related to current or historical Roche operations. The IRM was divided into two operable units. Operable Unit 1 (OU-1) targeted the CAMS breach and DNAPL source zone at IA-12 and consisted of *In Situ* Thermal Treatment (ISTT). OU-2 targeted the PCE+ groundwater plume around OU-1 and combined *in situ* chemical oxidation (ISCO) with Accelerated Remediation Technologies, Inc. in-well air stripping (ART-IWAS) technology.

This IA-12 OU-2 Progress Report provides a summary of OU-2 IRM activities, including ART-IWAS/ISCO system operations, supplemental ISCO injections, quantities of ozone and persulfate used, and groundwater monitoring results from pre-IRM baseline in May 2016 through October of 2018, which satisfies the reporting requirement set forth in the New Jersey Department of Environmental Protection (NJDEP) Permit-by-Rule (PBR) Notification Approval letters (Appendix A).

The ART-IWAS/ISCO IRM in IA-12 was implemented in accordance with the following NJDEP permits, which are included in Appendix A:

- *Long Term Monitoring Requirement Associated with New Jersey Pollutant Discharge Elimination System (NJPDES) Discharge to Groundwater (DGW) Authorization PBR for IA-1, 4, 6 &12,* issued by the NJDEP on August 13, 2015;
- NJDEP Air Pollution Control Permit (Permit Activity # PCP160003) dated September 16, 2016; and,

- *Modified – Long Term Monitoring Requirement Associated with NJPDES Discharge to Groundwater Authorization Permit-by-Rule for IA-1/4, IA-6, & IA-12* issued by the NJDEP on October 25, 2017.

The footprint of the ART-IWAS/ISCO treatment area encompassed approximately 46,000 square feet in the central portion of IA-12 surrounding the OU-1 boundary to the east, west, and south (Figure 2). Operation of the three ART-IWAS/ISCO systems (north, central, & south) within the IA-12 treatment area began in July 2016. The south ART-IWAS/ISCO system ceased operation in March and May 2017, respectively. The north and central treatment systems ceased operation in December 2017.

1.1 Hydrogeology

Roche submitted a Conceptual Site Model (CSM) Report (TRC and B. Kueper & Associates, Ltd., 2018) that defines the vertical hydrostratigraphic zonation into hydrogeologic units (HGUs) of the groundwater flow system and corresponding contaminant plumes and transport patterns at the Site. However, the groundwater IRMs were designed and implemented based on depth of apparent source area contamination below grade; therefore, treatment area remediation and monitoring results are reported as shallow, intermediate, or deep within the treatment zone.

1.2 Summary of Contaminants in Groundwater

The groundwater RI identified areas of elevated PCE+ concentrations exceeding the NJDEP Class II-A Ground Water Quality Standards (GWQS); typical values in the OU-2 area were greater than 1,000 but less than 10,000 micrograms per liter (µg/L) of PCE+ (TRC, 2014). A pre-design investigation (PDI) was conducted from January to April 2014, as reported in the IA-12 Pilot Test progress report for IA-12 (TRC, 2017a), to refine the extent and magnitude of the PCE+ plume, evaluate geologic controls and groundwater biogeochemistry, and verify the presence of DNAPL in the shallow portion of the bedrock aquifer in IA-12 near and beneath the breached portion of the CAMS.

Other volatile organic compounds (VOCs), including benzene, carbon tetrachloride, chlorobenzene and chloroform, exceeded their respective GWQS but at relatively minor concentrations. The majority of PCE+ in IA-12 has been observed within shallow groundwater, extending to a depth of approximately 50 feet below ground surface (bgs).

1.3 Previous Remediation Efforts

A pilot study was conducted from October 2014 to January 2015 in IA-12 to test and evaluate the effectiveness of, and establish design parameters for, treating PCE+ in groundwater using ART-IWAS enhanced with ISCO. Both ozone and persulfate oxidation technologies were tested. The results of the pilot study indicated that ART-IWAS/ISCO technology was effective in reducing PCE+ concentrations in groundwater (TRC, 2017a).

An ISTT Electrical Resistive Heating (ERH) system operated from March 10, 2015 to July 29, 2015 to remove source-area PCE+ in the bedrock matrix and groundwater within OU-1 (TRC, 2017b). The footprint of the ISTT area encompassed approximately 5,000 square feet in the central portion of IA-12 along the broken section of the CAMS pipeline, targeting the area where groundwater concentrations above 10,000 µg/L total PCE+ had been delineated in the PDI (Figure 2) The IA-12 OU-2 IRM, which is the subject of this progress report, is a separate IRM implemented to treat the PCE+ plume surrounding the OU-1 treatment zone. The OU-2 IRM encompassed the area outside of the OU-1 boundary where groundwater concentrations exceeded 1,000 µg/L.

1.4 Progress Report Objectives and Document Overview

This Progress Report summarizes the operations and performance of the IA-12 OU-2 ART-IWAS/ISCO IRM systems and documents the IRM effectiveness in remediating groundwater since operations began in July 2016. The Progress Report consists of the following sections:

- Section 1.0: Introduction;
- Section 2.0: ART-IWAS/ISCO System Operation;
- Section 3.0: Activated Persulfate Injections;
- Section 4.0: Groundwater Performance Monitoring;
- Section 5.0: Conclusions; and,
- Section 6.0: References.

2.0 ART-IWAS/ISCO SYSTEM OPERATION

The ART-IWAS system consisted of soil vapor extraction (SVE), IWAS, and groundwater recirculation in ART's proprietary remediation well design. The ISCO component consisted of ozone injection, with supplemental activated sodium persulfate (APS) injections in one portion of the OU-2 treatment zone, as summarized in Section 3.0. A system layout is provided on Figure 2.

The IA-12 ART-IWAS/ISCO treatment system consisted of three separate treatment systems, designated as the "North", "Central", and "South" systems. The three systems began operating in July 2016. The South system ceased operation in May 2017. The North and Central systems operated through December 2017.

2.1 ART-IWAS Wells

Twenty-five ART-IWAS wells were installed to a depth of 60 feet bgs. See Table 1 for a full list of ART-IWAS wells. Well construction logs are included in Appendix B.

2.2 ISCO Ozone Injection Wells

Ozone was injected through a network of 78 injection wells screened at three distinct depths in the IA-12 OU-2 treatment area. A full list of ozone injection wells is included in Table 1. Well construction logs are included in Appendix B.

ART-IWAS was combined with ISCO injection to increase the distribution and injection radius-of-influence (ROI) of oxidants via recirculation within the treatment area, as well as to further enhance the remedial effectiveness via flushing and stripping of VOCs.

2.3 Vapor Extraction Trenches

Sixteen vapor extraction trenches of varying lengths were installed across the three treatment zones along the perimeter of the main injection treatment areas of the OU-2 IRM. These trenches were installed to promote additional vapor recovery and capture sparged gases.

2.4 ART-IWAS/ISCO Systems Operation and Monitoring

2.4.1 Ozone Injection Monitoring Program

Ozone injections were monitored throughout system operation. Ozone was injected at a nominal five percent concentration into each group of injection wells at an average injection rate of 0.5 – 1 actual cubic feet per minute (acfm). Ozone flow was distributed as evenly as possible between each well in a given injection group, with well groups sequenced on sixty-minute cycles. The total permitted quantity and actual injected quantities of ozone are summarized in the table below. The total injected quantities were below the total permitted quantity.

Summary of Permitted and Actual Ozone Quantities

	North System	Central System	South System	Total
Actual	27,370 kg	13,609 kg	817 kg	41,796 kg
Permit	NA	NA	NA	69,000 kg

kg = kilograms

Adjustments were made to the injection scheme, as needed, throughout operation and included changing the injection flow rates, injection pressures, cycle times, and oxidant concentrations to optimize ozone delivery to the treatment zone. System observation data sheets and operational data are provided in Appendix C.

Oxidant distribution throughout the treatment area and depth intervals was assessed via observations at nearby monitoring wells. Groundwater geochemical parameters, including pH, temperature, dissolved oxygen (DO), specific conductivity, oxidation-reduction potential (ORP), and turbidity, were monitored in the field at regular intervals during injection, with DO and ORP being the primary tools used to assess oxidant distribution. Since oxygen is a primary breakdown product of ozone, increased DO concentrations in monitoring wells provided an indication of the distribution extent of ozone in the aquifer. ORP is a measure of the tendency of a chemical species to acquire electrons and thereby be reduced, with positive results indicating an oxidizing environment and negative results indicating a reducing environment; the goal for injecting ozone or other strong oxidants into the aquifer is to create a highly oxidizing environment in which organic compounds such as PCE are readily degraded via chemical oxidation. The DO concentrations and ORP measurements showed significant increases at most monitoring wells, indicating the system was operating as expected and that the ROI of the ozone injection wells and the ART-IWAS wells was within design parameters. Geochemical data are provided in Table 2.

Nearby utility manholes and outlets were periodically monitored for potential off-gassing or daylighting of oxidant. Soil vapor probes were installed and monitored for ozone and vapor pressure differential. No significant off-gassing or daylighting of ozone was observed at these locations.

2.4.2 Systems Operation and Monitoring

As part of the system operation and maintenance (O&M), TRC conducted routine Site visits during the initial startup. TRC then transferred O&M activities to Groundwater & Environmental Services, Inc. (GES) in September 2016. TRC continued to provide oversight for O&M activities. GES performed bi-weekly Site visits for the first six months of operation and bi-monthly O&M visits thereafter to confirm the systems were operating properly and to collect monthly vapor concentration readings and samples.

2.4.3 Systems Monitoring Data Summary

Total VOC concentrations in the extracted vapor stream were monitored using a photoionization detector (PID). Concentrations were consistently low (less than 1 part per million [ppm]) from each manifold and from the influent and effluent of the granular activated carbon (GAC) vessels. The Lower Explosive Limit (LEL) percentages were monitored within the treatment system enclosure and from the extracted vapors and were confirmed to be below the target levels. Moreover, the emissions stack was monitored for visible emissions, and none were observed. System O&M data are summarized in Appendix C.

2.4.4 Systems Air Emissions Monitoring Program and Results

Throughout system operation, and in compliance with NJDEP Air Permit #PCP160003 (Appendix A), influent and GAC effluent vapor samples were collected periodically from each of the SVE systems. The samples were collected using six-liter Summa canisters over a 30-minute period and were submitted to SGS-Accutest Laboratories of Dayton, New Jersey for VOC analysis.

Vapor treatment was also assessed using a PID, with influent and effluent readings collected from each vessel. The mid-treatment PID readings were used to assess the adsorptive capacity and the need for change-out of the primary GAC vessels.

Analytical results for air samples collected from each of the three systems are presented in Tables 3 through 5. Analytical results from the influent and effluent samples were used to determine the treatment efficiency of the vapor systems, ensure compliance with the air permit, and estimate VOC mass removal over time. Time-series plots for air sampling results are presented in Appendix D.

Air sampling results collected via PID through December 2017 showed that VOC concentrations in the primary GAC unit effluent did not exceed the 5 ppm limit established in NJDEP air permit PCP160003. Maximum VOC concentrations detected in the IA-12 GAC effluent were 0.269 ppm, demonstrating that there was adequate emissions control from the vapor treatment system GAC units through December 2017. Measured extraction flow rates were also consistently below the air permit limit.

An estimated total of approximately 25 pounds of VOC mass was removed via SVE operations through December 2017. VOC mass removal was calculated using the concentration results from the air samples and the volume of vapor removed, based on the recorded flow rates and the hours of operation (Appendix D).

3.0 ACTIVATED PERSULFATE INJECTIONS

The selected IRM technologies and original PBR (for IA-1/4, IA-6 & IA-12, dated August 13, 2015) for IA-12 groundwater treatment included two optional oxidation chemistries: ozone gas and APS. After nine months of ART-IWAS/ISCO using ozone, a small area in the central portion of the IA-12 IRM area (around well MW-80C) exhibited less reduction in PCE+ concentrations compared to the overall IRM area. Additional groundwater sampling was conducted at select wells between April and June 2017 to establish a target area for application of APS, a stronger oxidant, for focused ISCO treatment.

An area of approximately 2,500 square feet in the central portion of IA-12 was identified for APS treatment (Figure 3). A supplemental APS injection program was designed and implemented in 2017 to enhance PCE+ treatment in the central portion of the IA-12 IRM treatment area.

3.1 Modified PBR

The original PBR included APS injection for IA-12; however, a PBR modification, *Revised IA-1/4, IA-6 and IA-12 Discharge to Groundwater Permit by Rule- Request for Modification*, was submitted to the NJDEP on October 9, 2017 to revise the permitted injection locations and amendment quantities. The monitoring program from the original PBR was deemed to be adequate and was not altered, except that 10 monitoring wells in the immediate vicinity of the APS injections were designated to monitor sodium, sulfate, chloride, and metals (arsenic, barium, cadmium, chromium [total and hexavalent], copper, lead, and selenium). The PBR Modification was part of the combined PBR Modification for IA-1/4, IA-6, and IA-12 (*Modified PBR for IA-1/4, IA-6 & IA-12* dated October 25, 2017). Copies of the modification request and the permit modification are provided in Appendix A.

3.2 APS Injection Application

A 13.8-percent APS solution was used as the primary oxidant for the supplemental ISCO injections. A sodium bicarbonate buffer was mixed with the APS on-Site prior to injection into the wells. An 8-percent solution of hydrogen peroxide was used as an activator and injected separately, immediately after injection of the buffered APS solution to maximize treatment efficacy.

Four batches of APS were injected using the following wells (Figure 3): IW-35A and IW-35B; IW-41A1 and IW-41B2 (converted ozone injection wells); IW-10A and IW-10B2 (converted ozone wells); and IW-40A, IW-13A, IW-13B, and IW-40B.

During injections, groundwater was periodically pumped from nearby wells to distribute the injected oxidant over the target area and to control potential groundwater mounding. Pumping wells used at various times during the injections included ART-4, ART-5, ART-6, MW-80C, and IW-40B.

Groundwater levels in several wells surrounding the area of active injection were monitored to assess groundwater level mounding. If groundwater levels rose more than approximately 1 foot from static conditions, injections were halted and then reinitiated at a reduced flow rate to minimize mounding. In addition, local storm sewers were visually inspected for signs of potential oxidant daylighting.

APS injections were conducted between October 16 and November 2, 2017. Table 6 provides a summary of the injections, including the dates of the injections and volumes of persulfate and peroxide chemical applied on both a per-well and per-batch basis. The actual injected quantities for each of the injectate solutions were below the permitted quantities, as summarized in the table below.

Summary of Permitted and Applied Oxidant Chemicals

Permitted Chemical	Permitted Maximum Quantity	Injected Quantity
Sodium Persulfate	68,800 gallons (1)	5,519 gallons
Hydrogen Peroxide	30,000 pounds	1,854 pounds
Buffering Compound	20,000 pounds	971 pounds

(1) Volume represents the equivalent mass for a 13.8% solution (applied) relative to 95,000 gallons of 10% solution (maximum permitted).

On October 19, 2017, gas bubbles were noted in a concrete storm water channel located just to the south of the APS treatment area. The injection process was immediately halted, and specific conductivity and pH measurements from water in the storm water channel were collected; data from before, during, and after the injections were evaluated. The specific conductivity and pH levels before and after injections were relatively unchanged.

Based on these field measurements, it was determined that potential release into the storm water channel was limited to gas (either air from the ART-IWAS system or hydrogen from the hydrogen peroxide reaction) and that no significant release of sodium persulfate or hydrogen peroxide occurred. Nonetheless, the following additional precautions were put in effect for all subsequent injections:

- Sand bags were placed within the open channel to mitigate the potential for a release to be conveyed downstream in the storm sewer lines. Water accumulating in the channel was removed on a regular basis by a vacuum truck.
- The vacuum truck remained on stand-by as a precaution to quickly recover water from the storm sewer system if a potential release was observed.
- The frequency of storm sewer monitoring was increased in the open channel and in select storm lines near the injection areas.
- Groundwater was extracted from wells ART-4 and ART-6 adjacent to the Valley Drain line concurrent with the injections to minimize the potential for migration of treatment chemicals into the storm system.

Consistent with the requirements of the PBR, the potential release and associated response actions were reported to the NJDEP in a letter dated November 14, 2017 (Appendix A). During all subsequent injection events in IA-12, the local storm sewers were monitored during and after each injection, and no further issues were noted.

4.0 GROUNDWATER PERFORMANCE MONITORING

4.1 Installation of Additional Monitoring Wells and Probes

Fourteen additional groundwater monitoring wells were installed, in addition to existing wells, to monitor groundwater quality within the IA-12 OU-2 ART-IWAS/ISCO treatment area; twelve, 1-inch vapor points were also installed. The wells were installed by NJ-licensed drillers under TRC supervision from June to October 2015. Well construction information is included in Table 1. Well locations are shown on Figure 2. As-built well construction logs are provided in Appendix B.

4.2 Groundwater Monitoring Program

During IRM operation, groundwater in OU-2 was monitored and sampled for laboratory analyses in compliance with the PBR to track oxidant distribution, evaluate the ART-IWAS/ISCO systems' treatment efficiency, and demonstrate the absence of contaminant migration. Additional sampling was conducted for metals specific to the APS treatment area. All sampling was performed in accordance with the NJDEP Field Sampling Procedures Manual, the Site Quality Assurance Project Plan, and the monitoring requirements defined in the PBR authorization dated August 13, 2015.

Groundwater sampling and laboratory analyses were performed in the IA-12 OU-2 as follows:

- Pre-system startup/baseline (May 2016);
- Six weeks post-startup (August 2016); and
- Quarterly during system operation (November 2016 - October 2018).

Groundwater measurements and analyses included:

- Field-measured geochemical indicator parameters: pH, temperature, DO, specific conductivity, ORP, salinity, and turbidity;
- Target Compound List (TCL) VOCs+15;
- Iron and manganese; and
- Sodium, sulfate, chloride, and eight metals (limited to 10 designated APS treatment-area monitoring wells).

Groundwater samples were collected using low-flow purging and sampling methods from the mid-point of the saturated screen section at the following treatment zone monitoring wells:

- **Overburden and shallow bedrock wells (elevation greater than 80 feet above mean sea level [msl]):**

  MW-239, MW-294A, MW-436A, MW-442A, MW-60F, MW-60R, MW-443A, MW-225A, MW-444A, MW-365A, MW-80C, MW-445A, MW-60G, MW-438B, MW-438A, MW-359A, MW-360A, MW-440A, MW-362A, MW-362B, MW-60M, MW-439A, MW-435B, MW-435A, MW-437B, MW-437A, and MW-295A.

- **Intermediate bedrock wells (elevation between 50 and 80 feet above msl):** MW-295B, MW-436B, MW-442B, MW-60-Z2R, MW-443B, MW-225B, MW-24C, MW-444B, MW-365B, MW-445B, MW-360B, MW-359B, MW-80-Z2R, MW-439B, MW-362B, and MW-438B.
- **Deep bedrock wells (elevations between 0 and 50 feet above msl):** MW-294C, MW-225C, MW-364C, MW-239C, and MW-60 G-S3.

Additional monitoring wells (MW-24, MW-113, MW-13B, MW-364B, MW-363C, MW-363B, and MW-358B) and injection wells (IW-13B, IW-11B, IW-41B2, IW-35B, IW-40B) were selectively sampled in April and June 2017 to further evaluate PCE+ concentrations in the north-central portion of the IRM treatment area. A subset of these wells was also used for groundwater quality monitoring associated with the APS treatment (see Sections 4.3.2 and 4.3.3).

Table 7 provides the overall groundwater sampling and analysis plan, including the APS groundwater sampling and analysis plan. The locations of the monitoring wells are shown on Figure 2.

4.3 Groundwater Analytical Results

4.3.1 DO/ORP Results

Geochemical results, including DO and ORP, can be found in Table 8. Time-series plots of ORP and DO concentrations for the target treatment area wells are included in Appendix E. The elevated ORP values and DO concentrations provided strong evidence that oxidant was effectively distributed throughout the IRM treatment area. The variability in the ORP value and DO concentrations is attributable to the heterogeneity of the fractured bedrock environment.

4.3.2 APS Treatment Parameters

Beginning in October 2017, groundwater in the APS injection area was monitored for constituents directly associated with APS (chloride, sodium, and sulfate) before, during, and after the period of APS injections. Sampling frequencies and parameters were consistent with approved sampling plans in both the original PBR and the PBR Modification. Sampling at the 16 wells specific to the persulfate ISCO program continued through October 2018; ten of those wells were also sampled for metals (see Section 4.3.4). A summary of the results of persulfate indicators analysis is provided in Table 9.

Overall, analytical results showed sufficient distribution of APS in groundwater throughout the targeted IA-12 treatment area.

4.3.3 PCE+ Results

A summary of the groundwater sampling results for VOCs is provided in Table 10. Time-series plots of PCE+ concentrations are presented in Appendix F. Laboratory reports and NJDEP Electronic Data Deliverable Submissions (electronic correspondence) are included in Attachment 1.

Overall, analytical results showed a reduction in total PCE+ concentrations in groundwater throughout the IA-12 treatment area following implementation of the IRM.

***<u>Baseline Sampling Results</u>*: May 2016 baseline groundwater sampling results indicated elevated concentrations of PCE+ in shallow wells throughout the IA-12 OU-2 target treatment zone. Total PCE+ concentrations ranged from < 100 µg/L to >10,000 µg/L, with higher concentrations near the central portion of IA-12, including wells MW-80C (10,457 µg/L), MW-365A (1,596 µg/L), and MW-359A (987 µg/L). Elevated concentrations were also observed at MW-294A (2,685 µg/L), located in the northeast portion of the OU-2 area. Figure 4 presents PCE+ isopleths for the baseline results in shallow treatment zone monitoring wells in the IA-12 OU-2 IRM area.

Baseline PCE+ concentrations from intermediate treatment zone wells showed PCE+ concentrations ranging from below 100 µg/L to greater than 3,000 µg/L. Elevated concentrations of PCE+ above 1,000 µg/L were detected near the center of the IA-12 OU-2 area at MW-359B (3,110 µg/L), to the northeast at MW-80-Z2R (1,583 µg/L) and MW-60-Z2R (1,216 µg/L), and in the southern portion of the treatment area at MW-24C (1,199 µg/L). Figure 5 presents isopleths of baseline PCE+ concentrations in intermediate and deep treatment zone monitoring wells in the IA-12 OU-2 IRM area.

PCE+ concentrations in deep wells ranged from 140 µg/L (MW-60G-S3) to greater than 1,000 µg/L. The only deep monitoring well with a PCE+ concentration over 1,000 µg/L during the baseline event was MW-239C (1,199 µg/L), located in the southern area of IA-12. Deep wells were utilized to monitor for the potential migration of PCE+ below the target treatment zone.

***<u>System Shutoff (May & December 2017)</u>*: The North and Central treatment systems ceased operation in December 2017. The South treatment system ceased operation in May 2017, as quarterly groundwater sampling results collected in January and February 2017 showed significant and widespread decreases in PCE+ concentrations from baseline levels.

South Treatment Area - January and February 2017 sampling results showed that PCE+ concentrations were reduced to below 100 µg/L at all locations in the different zones, except for intermediate well MW-439B (174 µg/L). Total PCE+ concentrations in shallow wells ranged from 0.51 µg/L (MW-438A) to 47.6 µg/L (MW-225A), and from 30.2 µg/L (MW-225B) to 174 µg/L (MW-439B) for intermediate wells. Total PCE+ in deep wells ranged from 22 µg/L (MW-239C) to 95 µg/L (MW-225C), indicating no notable migration of PCE+ downward occurred due to IRM operations.

North and Central Treatment Areas - Groundwater analytical results for the December 2017 event indicated an overall significant decrease in PCE+ concentrations in the North and Central treatment areas. All shallow groundwater monitoring wells, and all but five of the intermediate and deep monitoring wells exhibited a decrease in PCE+ concentrations. Total PCE+ concentrations were reduced to below 1,000 µg/L at all but two monitoring wells (MW-80C and MW435B). Total PCE+ concentrations ranged from 1.0 µg/L (MW-442A) to 2,810 µg/L (MW-80C) in shallow wells, and from 0.59 µg/L (MW-362B) to 1,200 µg/L (MW-435B) in intermediate wells. Total PCE+ in deep wells ranged from 103 µg/L (MW-225C) to 239 µg/L (MW-294C), again indicating no measurable migration of PCE+ downward due to treatment.

An average of approximately 69 percent reduction in total PCE+ dissolved mass was achieved in the treatment zone (83 percent in shallow wells) by December 2017, compared to baseline levels. Appendix F provides time-series plots of PCE+ concentrations and percent mass reductions.

<u>Post-System Shutdown Results (October 2018)</u>**:** Consistent with the PBR monitoring requirements, quarterly groundwater monitoring continued through October 2018 in the IA-12 OU-2 IRM area.

Comparison of the October 2018 results with baseline concentrations: The October 2018 data showed a decrease in total PCE+ concentrations in most shallow (14 out of 20) and intermediate (12 out of 17) and all deep treatment area monitoring wells compared to 2016 baseline levels.

Total PCE+ concentrations in all but three shallow wells (MW-60G, MW-80C, and MW-435A) decreased or remained below 1,000 µg/L. Total PCE+ concentrations in October 2018 ranged from 1.0 µg/L (MW-239) to 3,079 µg/L (MW-80C). Six outer monitoring wells (MW-435B, MW-225A, MW-440A, MW-438A, MW-362A, and MW-60G) along the western margins of the OU-2 area showed stable or increasing total PCE+ concentrations. The trends at the outer wells were likely due to a combination of increasing concentrations of degradation products, desorption/back diffusion, and migration from upgradient (untreated) areas.

All intermediate wells except MW-435B had total PCE+ concentrations that remained below 1,000 µg/L. Total PCE+ concentrations in intermediate treatment zone groundwater ranged from 0.38 µg/L (MW-443B) to 1,100 µg/L (MW-435B) during the October 2018 sampling event.

Total PCE+ concentrations in deep wells ranged from non-detected (MW-294C) to 760 µg/L (MW-24C) in October 2018. The decrease of total PCE+ concentrations in deep wells confirmed that no PCE+ migration below the treatment zone occurred due to active treatment.

Figures 4 and 5 present total PCE+ concentration isopleths for shallow treatment zone and intermediate/deep treatment zone groundwater, respectively, at baseline (May 2016) and for the last quarterly event in October 2018. Appendix F presents time-series plots of PCE+ concentrations in each well; plots for key IA-12 wells are also shown on Figures 4 and 5. Key results and conclusions drawn from these results are:

- Total PCE+ concentrations decreased in most wells.
- The highest baseline PCE+ concentrations (> 10,000 µg/) in the shallow treatment zone have been greatly reduced. As of October 2018, the highest remaining total PCE+ concentration was 3,079 µg/L.
- The footprint of the 1,000 µg/L contour areas (inclusive of areas in the northwest portion of IA-12 OU-2, which emanated from off-Site) were reduced by 58 percent in the shallow treatment zone and 55 percent in the intermediate treatment zone.
- An overall average of approximately 55 percent reduction in total PCE+ concentrations was estimated for the intermediate and deep treatment zones by October 2018 data from baseline levels (Appendix F).

***Comparison of October 2018 results with December 2017 concentrations*:** Data collected after cessation of active ART-IWAS/ISCO treatment can provide a measure of the magnitude of potential rebound of PCE+ concentrations in groundwater due to desorption/back diffusion from the bedrock matrix or recontamination of IA-12 groundwater from off-Site, upgradient areas north of IA-12.

The October 2018 results indicate that PCE+ concentrations have increased compared to levels detected at the time of cessation of active treatment (December 2017). An approximate 14 percent increase in PCE+ concentrations due to rebound and/or recontamination was observed approximately 10 months after active treatment measures were completed.

4.3.4 Metals Results

Prior to, during, and after APS treatment, 10 monitoring wells in the treatment area were sampled and analyzed for metals as specified in the PBR Modification. Table 11 provides a summary of metals results, and Figure 6 presents results over time at each of the wells sampled.

Metals concentrations generally increased in most of the 10 sampled monitoring wells, as expected, due to the increased oxidative state in groundwater created by the APS injections. Metals concentrations exhibited a downward trend after the 8-week sampling event in January 2018. After the second quarterly sampling event in July 2018, only two wells (MW-80C and MW-359A) exhibited exceedances of GWQS; sampling was discontinued at 8 of the 10 wells after each had exhibited two or more consecutive quarters with all metals concentrations below their respective GWQS.

5.0 CONCLUSIONS

The IA-12 OU-2 ART-IWAS/ISCO remediation system operated from July 2016 through December 2017, with the exception of the southern portion of the treatment system, which concluded operation in May 2017. The combined systems operated within the design parameters and NJDEP permit requirements. Groundwater analytical results, collected pre-startup and post-operation, indicate that the ART-IWAS/ISCO system has been successful in reducing the PCE+ concentrations from pre-IRM levels.

Groundwater sampling results through October 2018 showed that there has been a significant overall reduction in PCE+ concentrations, as summarized below:

- Total PCE+ concentrations have been significantly reduced from a starting concentration of 10,457 µg/L in well MW-80C to a current (October 2018) concentration of 3,079 µg/L;
- An overall 69 percent reduction in PCE+ concentrations was achieved at system shutoff in December 2017, compared to the baseline concentrations (May 2016); and
- Only minor rebound/recontamination was observed, as of October 2018, with an overall 55 percent reduction in PCE+ concentrations by October 2018, 10 months after cessation of IRM systems.

The post-APS injection sampling results indicate that metals concentrations have returned to or below their pre-injection levels, with all metals concentrations below each applicable GWQS at 8 of the 10 wells sampled.

Roche has completed its efforts to remediate the IA-12 CAMS plume, and, since these PCE+ impacts are not associated with historical on-Site Roche operations, Roche will not conduct any further remediation to address the remaining groundwater impacts associated with the CAMS. Furthermore, since the PBR groundwater monitoring requirements have been met, and since the PCE+ impacts in IA-12 are attributed to the CAMS, no further sampling will be conducted for the IA-12 OU-2 IRM, except for wells MW-80C and MW-359A. Monitoring for metals will continue on a quarterly basis for each well until two consecutive quarters with no metals GWQS exceedances are observed, or, if minor exceedances persist, until concentrations show a clearly stable trend and remain at or below their pre-APS treatment levels.

6.0 REFERENCES

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